

Passive Oxygen Insufflation Is Superior to Bag-Valve-Mask Ventilation for Witnessed Ventricular Fibrillation Out-of-Hospital Cardiac Arrest

Bentley J. Bobrow, MD
Gordon A. Ewy, MD
Lani Clark, BS
Vatsal Chikani, MPH
Robert A. Berg, MD
Arthur B. Sanders, MD
Tyler F. Vadeboncoeur, MD
Ronald W. Hilwig, DVM, PhD
Karl B. Kern, MD

From the Arizona Department of Health Services Bureau of Emergency Medical Services and Trauma System, Phoenix, AZ (Bobrow, Clark, Chikani); Department of Emergency Medicine, Maricopa Medical Center, Phoenix, AZ (Bobrow); the University of Arizona Sarver Heart Center (Bobrow, Ewy, Clark, Sanders, Hilwig, Kern), the Departments of Medicine (Ewy), and Emergency Medicine (Bobrow, Sanders), University of Arizona College of Medicine, Tucson, AZ, and Critical Care Medicine, Children's Hospital of Philadelphia, Philadelphia, PA (Berg); Department of Emergency Medicine, Mayo Clinic, Jacksonville, FL (Vadeboncoeur).

Study objective: Assisted ventilation may adversely affect out-of-hospital cardiac arrest outcomes. Passive ventilation offers an alternate method of oxygen delivery for these patients. We compare the adjusted neurologically intact survival of out-of-hospital cardiac arrest patients receiving initial passive ventilation with those receiving initial bag-valve-mask ventilation.

Methods: The authors performed a retrospective analysis of statewide out-of-hospital cardiac arrests between January 1, 2005, and September 28, 2008. The analysis included consecutive adult out-of-hospital cardiac arrest patients receiving resuscitation with minimally interrupted cardiopulmonary resuscitation (CPR) consisting of uninterrupted preshock and postshock chest compressions, initial noninvasive airway maneuvers, and early epinephrine. Paramedics selected the method of initial noninvasive ventilation, consisting of either passive ventilation (oropharyngeal airway insertion and high-flow oxygen by nonrebreather facemask, without assisted ventilation) or bag-valve-mask ventilation (by paramedics at 8 breaths/min). The authors determined adjusted neurologically intact survival from hospital and public records and by telephone interview and mail questionnaire. The authors compared adjusted neurologically intact survival between ventilation techniques by using generalized estimating equations.

Results: Among the 1,019 adult out-of-hospital cardiac arrest patients in the analysis, 459 received passive ventilation and 560 received bag-valve-mask ventilation. Adjusted neurologically intact survival after witnessed ventricular fibrillation/ventricular tachycardia out-of-hospital cardiac arrest was higher for passive ventilation (39/102; 38.2%) than bag-valve-mask ventilation (31/120; 25.8%) (adjusted odds ratio [OR] 2.5; 95% confidence interval [CI] 1.3 to 4.6). Survival between passive ventilation and bag-valve-mask ventilation was similar after unwitnessed ventricular fibrillation/ventricular tachycardia (7.3% versus 13.8%; adjusted OR 0.5; 95% CI 0.2 to 1.6) and nons shockable rhythms (1.3% versus 3.7%; adjusted OR 0.3; 95% CI 0.1 to 1.0).

Conclusion: Among adult, witnessed, ventricular fibrillation/ventricular tachycardia, out-of-hospital cardiac arrest resuscitated with minimally interrupted cardiac resuscitation, adjusted neurologically intact survival to hospital discharge was higher for individuals receiving initial passive ventilation than those receiving initial bag-valve-mask ventilation. [Ann Emerg Med. 2009;54:656-662.]

Provide [feedback](http://www.annemergmed.com) on this article at the journal's Web site, www.annemergmed.com.

0196-0644/\$-see front matter
Copyright © 2009 by the American College of Emergency Physicians.
doi:10.1016/j.annemergmed.2009.06.011

INTRODUCTION

Background

Out-of-hospital cardiac arrest is a leading cause of death in the United States, with estimates ranging from 166,000 to 310,000 events per year.¹⁻² Long-term survival is typically less

than 10%, but recent studies have shown that new emergency medical services (EMS) protocols can substantially improve survival for adult out-of-hospital cardiac arrest victims.³⁻⁷

New approaches to resuscitation emphasize chest compression continuity at the earliest stages of resuscitation. To

Editor's Capsule Summary

What is already known on this topic

When treating out-of-hospital cardiac arrest, rescuers may provide initial bag-valve-mask ventilation. A newer approach involves initial passive ventilation with a non-rebreather mask only, without active ventilation.

What question this study addressed

This retrospective analysis of a statewide EMS database, restricted to patients provided care under a minimally interrupted cardiac resuscitation protocol, compared survival in 560 patients who received bag-valve-mask ventilation and 459 who received passive ventilation.

What this study adds to our knowledge

Compared with bag-valve-mask ventilation, initial passive ventilation doubled survival from witnessed, ventricular fibrillation out-of-hospital cardiac arrest, though no benefit was seen in those with non-shockable rhythms.

How this might change clinical practice

Initial passive ventilation may provide a viable out-of-hospital cardiac arrest treatment alternative and warrants validation with a randomized controlled trial.

achieve this goal, the latest protocols defer advanced airway interventions such as endotracheal intubation, substituting basic-level airway measures. One example was reported in a rural Wisconsin EMS system using cardiocerebral resuscitation, a strategy consisting of continuous chest compressions accompanied by initial passive ventilation only by nonrebreather mask.^{6,7} In Arizona, we implemented a similar minimally interrupted cardiopulmonary resuscitation (CPR) protocol emphasizing continuous chest compressions with minimal interruptions, initial basic airway management, single defibrillation attempts, early epinephrine administration, and delayed endotracheal intubation.⁴ Under minimally interrupted cardiac resuscitation, paramedics in Arizona provide initial airway management with passive ventilation or standard bag-valve-mask ventilation.

Importance

Previous studies have linked assisted positive-pressure ventilation to impaired CPR coronary circulation and worsened patient neurologically intact survival.⁸ Aufderheide et al⁹ also showed that excessive ventilation is common during out-of-hospital cardiac arrest resuscitation. Passive ventilation offers a

simpler approach to CPR oxygen delivery without positive pressure application. However, the relative merits of passive ventilation and bag-valve-mask ventilation remain unknown.

Goals of This Investigation

In this study, we compared outcomes of out-of-hospital cardiac arrest patients receiving minimally interrupted cardiac resuscitation with initial passive ventilation with those receiving minimally interrupted cardiac resuscitation with initial bag-valve-mask ventilation.

MATERIALS AND METHODS

Setting and Selection of Participants

The state of Arizona encompasses 113,635 square miles and 15 counties. According to the 2006 census estimate, Arizona had a population of 6.2 million, yielding 45 persons per square mile. There were 3.1 million (50%) female residents and 3.1 million (50%) male residents. The median age was 34.6 years. Twenty-six percent of the population was younger than 18 years and 13% was older than 65 years. The median income of households in Arizona was \$47,265. For people reporting one race alone, 77% were white, 4.5% were American Indian or Alaska Native, 3% were black, 2% were Asian, less than 0.5% were Native Hawaiian or Pacific Islander, and 10% described themselves as another race. Twenty-nine percent reported their ethnicity as Hispanic or Latino.¹⁰

In 2004, the Arizona Bureau of Emergency Medical Services and Trauma System established the Save Hearts in Arizona Registry and Education (SHARE) program as a means to address the public health problem of out-of-hospital cardiac arrest. The statewide SHARE program collects data from multiple EMS systems in urban, suburban, and rural settings, as previously described.^{4,11}

Because out-of-hospital cardiac arrest has been designated a public health issue in Arizona and the goal of the SHARE program is quality improvement, the data collected were exempt from the Health Insurance Portability and Accountability Act. Permission to publish deidentified SHARE program data was obtained from the Arizona Department of Health Services Human Subjects Review Committee, as well as the University of Arizona Institutional Review Board.

Data Collection and Processing

The SHARE program collects Utstein-style information on patient demographics, event circumstances, response intervals, presenting rhythm, bystander CPR, treatment and procedures, and initial outcomes from EMS incident reports for 60 EMS agencies currently covering approximately 80% of the state population.¹¹ Final outcomes are obtained through local hospitals and the Office of Vital Statistics at the Arizona Department of Health Services. Data collection for this report was begun on January 1, 2005, and ended September 28, 2008.

Cardiac arrest was defined as the absence of cardiac mechanical activity, determined by the absence of a pulse and

the lack of normal breathing. All adults (age >18 years) with out-of-hospital cardiac arrest for whom resuscitation was initiated were included.

Cardiac arrest rhythms documented by EMS providers included the nonshockable rhythms of asystole and pulseless electrical activity and the shockable rhythms of ventricular fibrillation and pulseless ventricular tachycardia. Victims with obvious signs of death (eg, rigor mortis, lividity) or do not resuscitate documentation on EMS arrival were excluded because resuscitation efforts were not initiated per standard protocol. Other exclusion criteria were aged younger than 18 years, cardiac arrest in adults witnessed by EMS personnel, and cardiac arrest as a result of trauma, drowning, or other suspected noncardiac causes.

Interventions

We introduced the minimally interrupted cardiac resuscitation protocol to EMS systems in Arizona in January 2005. Twenty-five of the 60 fire departments submitting out-of-hospital cardiac arrest data to the SHARE program independently self-selected to use the minimally interrupted cardiac resuscitation protocol for their treatment of out-of-hospital cardiac arrest. The minimally interrupted cardiac resuscitation protocol consisted of (1) 200 uninterrupted pre-shock chest compressions; (2) 200 uninterrupted postshock chest compressions before pulse check or rhythm analysis; (3) delayed endotracheal intubation for 3 cycles of 200 compressions and rhythm analysis; and (4) attempted intravenous or intraosseous epinephrine before or during the second cycle of chest compressions. Paramedics self-reported compliance by documenting all 4 of these minimally interrupted cardiac resuscitation elements. The description of the EMS protocol, reports of its effectiveness, and criteria for minimally interrupted cardiac resuscitation compliance have been previously published.⁴

Although the original design for minimally interrupted cardiac resuscitation called for passive ventilation to avoid excessive ventilation, at the earliest stages of implementation EMS personnel were reluctant to use this strategy. Therefore, we permitted performance of basic airway management with passive ventilation or bag-valve-mask ventilation at the paramedics' discretion. Paramedics performed passive ventilation or bag-valve-mask ventilation during the initial 3 cycles of 200 chest compressions. After this point, if indicated, paramedics performed endotracheal intubation with positive-pressure ventilation for the remainder of the resuscitation.

Data elements included in the enhanced Utstein-style database were manually extracted case by case by the SHARE program research and quality improvement director. After review of EMS documentation, only cases that met all 4 of the above criteria were included in this investigation.

We previously reported a comparison of patients receiving minimally interrupted cardiac resuscitation with those receiving standard treatment, encompassing a total of 3,508 patients between January 1, 2005, and November 22, 2007. This

current report uses an overlapping period with 5,097 total arrests extending the database analysis until September 28, 2008. This report also focuses exclusively on the subset of patients receiving minimally interrupted cardiac resuscitation.⁴

Outcome Measures

The primary outcome measure was neurologically intact survival to hospital discharge, determined by review of hospital records. We defined neurologically intact survival as discharge to home or rehabilitation facility. We defined non-neurologically intact survival as discharge to nursing or long-term care facility or death. Secondary outcome measures were return of spontaneous circulation, survival to hospital admission, and survival to discharge with a favorable neurologic outcome as measured by the Cerebral Performance Category (CPC) scale.¹²

We assessed neurologic outcome with mail and telephone survey versions of the Cerebral Performance Score. This approach has been previously described and validated.¹³ Survivors were contacted by mail and asked whether they were willing to participate in a telephone interview or complete a questionnaire. Survivors had the option of refusing to participate. Answers to questions given during the telephone interview or on the written questionnaire were used to determine CPC scores. CPC scores ranged from 1 (good cerebral performance) to 4 (coma or vegetative state).¹² Favorable neurologic outcome was defined as a CPC score of 1 or 2, and unfavorable neurologic outcome was defined as a CPC score of 3 or 4.

Because the decision to provide passive ventilation versus bag-valve-mask ventilation generally occurred before the first rhythm analysis, we chose to compare outcomes among all patients meeting inclusion criteria. However, we chose a priori to specifically analyze the subgroup with witnessed ventricular fibrillation/ventricular tachycardia arrest.

We used Microsoft Access for Windows (Microsoft Office; Microsoft Corp, Redmond, WA) for database management and SAS version 9.1.3 (SAS Institute, Inc., Cary, NC) for statistical analysis.

We evaluated the association between adjusted neurologically intact survival and ventilation technique by using generalized estimating equations with a logit link function and exchangeable correlation structure to account for clustering within EMS agency. Models were adjusted for age (years), bystander CPR (yes versus no), initial rhythm (shockable versus nonshockable), location of cardiac arrest (home versus public/medical facility), sex (female versus male), bystander-witnessed arrest (yes versus no), and EMS response time (depart station to arrival on scene, minutes). Odds ratios (ORs) for adjusted neurologically intact survival and 95% confidence intervals (CIs) were determined. Where available for survivors, we compared CPC scores by using univariable ORs with exact CIs.

RESULTS

Reports of 5,097 total EMS-attended out-of-hospital cardiac arrests were documented in the Arizona statewide Utstein-style

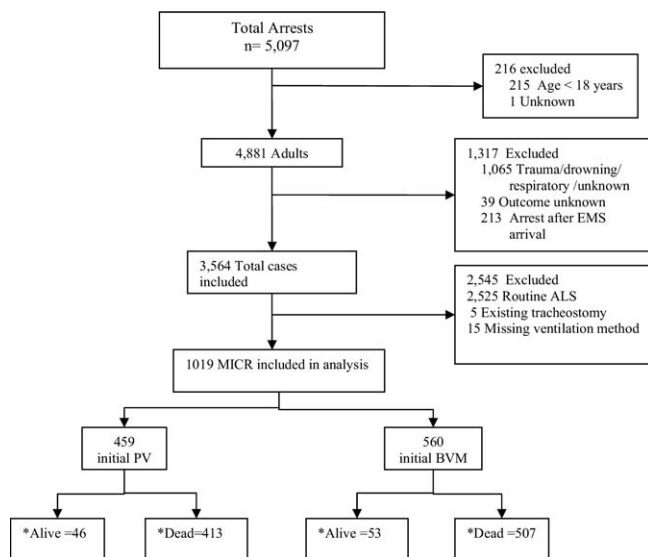


Figure. Patient enrollment and outcome. ALS, Advanced Life Support; BVM, bag-valve-mask ventilation; EMS, Emergency Medical Services; MICR, Minimally interrupted cardiac resuscitation; PV, passive ventilation. *based on survival to hospital discharge.

EMS database from January 1, 2005, to September 28, 2008. For this analysis, we included the 1,019 cases receiving minimally interrupted cardiac resuscitation (Figure). Of these 1,019 arrests, 459 patients received passive ventilation and 560 received bag-valve-mask ventilation. There were no differences in age, sex, location of arrests, bystander CPR, witnessed arrests, first documented ventricular fibrillation/ventricular tachycardia rhythm, and EMS dispatch-to-arrival interval (Table 1).

Overall adjusted neurologically intact survival to hospital discharge was similar between passive ventilation and bag-valve-mask ventilation (adjusted OR 1.2; 95% CI 0.8 to 1.9) (Table 2). In the witnessed ventricular fibrillation/ventricular tachycardia subset, adjusted neurologically intact survival to discharge was higher for passive ventilation (39/102; 38.2%) than bag-valve-mask ventilation (31/120; 25.8%) (adjusted OR 2.5; 95% CI 1.3 to 4.6). Among unwitnessed ventricular fibrillation/ventricular tachycardia patients, survival to discharge was similar between passive ventilation and bag-valve-mask ventilation (adjusted OR 0.5; 95% CI 0.2 to 1.6). Among patients with nonshockable rhythms, survival to discharge was similar between passive ventilation and bag-valve-mask ventilation (adjusted OR 0.3; 95% CI 0.1 to 1.0). (Full regression models available in Table E1, available online at <http://www.annemergmed.com>.)

Of the 99 survivors, CPC score was available from 60 survivors. CPC was 1 or 2 for 32 of 33 (97%) bag-valve-mask ventilation survivors and 26 of 27 (96%) passive ventilation survivors. Neurologic outcomes were similar between passive ventilation and bag-valve-mask ventilation survivors (exact OR 1.22; 95% CI 0.02 to 99.6).

LIMITATIONS

An important limitation of this observational study is that the intervention was not tested in a randomized fashion. The results of our study may be subject to self-selection bias. Although we attempted to control for confounding variables, it is possible that there were characteristics of the out-of-hospital cardiac arrest victims or providers that led EMS personnel to select a particular ventilation method.

Our findings are also limited by the lack of CPR process data and our inability to accurately quantify and qualify the chest compressions and ventilations. We do not know whether the difference in survival was due to the different ventilation techniques or the possible indirect effect of CPR quality between the 2 groups. In addition, it is possible that the EMS providers who chose to use bag-valve-mask ventilation hyperventilated their patients above the recommended rate and tidal volume, thereby worsening outcomes in that subgroup. EMS providers may have preferentially chosen either ventilation technique after becoming familiar with the protocol.

Our study evaluates only initial airway interventions and does not evaluate the potential effect of later airway management. Our study does not compare endotracheal intubation with other airway techniques such as supraglottic airway devices. Although our protocol indicated benefit from early passive ventilation, we could not determine the potential benefit of more prolonged passive ventilation or passive ventilation provided during the entire resuscitation.

Finally, our study design does not control for postarrest care at receiving hospitals. However, very few patients, if any, in either group received guideline-based postarrest care during the study.

DISCUSSION

For decades, the advanced cardiac life support guidelines for cardiac arrest have advocated positive-pressure ventilation, traditionally delivered through bag-valve-mask ventilation or endotracheal intubation.¹⁴ Yet Aufderheide et al⁹ suggest adverse consequences from excessive positive-pressure ventilation, including increased intrathoracic pressure and decreased coronary perfusion pressure. Advanced airway insertion efforts or bag-valve-mask ventilation may also disrupt CPR chest compression continuity. Passive ventilation theoretically avoids these unintended effects. However, few studies have directly compared passive ventilation with bag-valve-mask ventilation. Our findings suggest that among witnessed ventricular fibrillation/ventricular tachycardia out-of-hospital cardiac arrest patients receiving minimally interrupted cardiac resuscitation, patients treated with passive ventilation were more likely to survive to hospital discharge than those treated with bag-valve-mask ventilation. The 38.2% neurologically intact survival to hospital discharge for patients with witnessed ventricular fibrillation/ventricular tachycardia arrest is comparable to the 39% neurologic intact survival reported by Kellum et al⁶ for ventricular fibrillation/ventricular

Table 1. Demographics of study participants and event characteristics by ventilation method.

Characteristics (N=1,019)	PV (n=459)	BVM (n=560)	OR (95% CI)
Age, y, mean (SD)	66.6 (14.5)	64.8 (16.0)	1.0 (1.0–1.01)
Male	313/459 (68.2)	377/560 (67.3)	1.0 (0.8–1.4)
Location			
Home	323/459 (70.4)	393/560 (70.2)	1.00
Public place	73/459 (15.9)	76/560 (13.6)	0.8 (0.6–1.2)
Medical facility	63/459 (13.7)	91/560 (16.3)	1.2 (0.8–1.7)
Witnessed % (No.)	200/459 (43.6)	252/560 (45.0)	0.9 (0.7–1.2)
Bystander CPR performed	177/459 (38.6)	242/560 (43.2)	0.8 (0.6–1.1)
Initial rhythm*			
Shockable (ventricular fibrillation/ ventricular tachycardia)	143/459 (31.2)	178/560 (31.8)	1.00
Nonshockable	316/459 (68.9)	381/560 (68.2)	1.0 (0.8–1.3)
EMS dispatch to arrival time, min, median (IQR)	5.0 (2.0)	5.0 (2.0)	1.0 (0.9–1.0)

IQR, Interquartile range.

*Missing data were excluded from analysis.

Table 2. Generalized estimating equation predicting overall adjusted neurologically intact survival from passive and bag-valve-mask ventilation.

Outcomes	PV (n=459), n/N (%)	BVM (n=560), n/N (%)	Adjusted OR (95% CI)
ROSC	123/459 (26.8)	169/560 (30.2)	0.8 (0.7–1.0)
Adjusted neurologically intact survival to hospital discharge	46/459 (10.0)	53/560 (9.5)	1.2 (0.8–1.9)
Adjusted neurologically intact survival with witnessed VF/VT	39/102 (38.2)	31/120 (25.8)	2.5 (1.3–4.6)
Adjusted neurologically intact survival with VF/VT, not witnessed	3/41 (7.3)	8/58 (13.8)	0.5 (0.2–1.6)
Adjusted neurologically intact survival with nonshockable rhythm	4/316 (1.3)	14/381 (3.7)	0.3 (0.1–1.0)

ROSC, Return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

tachycardia arrest using cardiocerebral resuscitation with passive ventilation.

Several studies support the strategy of passive ventilation. Steen et al¹⁵ and Hayes et al¹⁶ verified adequate oxygenation and improved survival in swine out-of-hospital cardiac arrest models with passive ventilation. Several previous studies have demonstrated improved outcomes with bystander-administered chest compression–only CPR without ventilations. An observational study from the SOS-KANTO (Survey of Survivors of Out-of-Hospital Cardiac Arrest in the Kanto Region of Japan) Group in Japan examined 4,068 adult out-of-hospital cardiac arrests and found that the provision of chest compressions alone was associated with better survival than the delivery of conventional CPR.¹⁷ Using similar methodology of another large cohort, Iwami et al¹⁸ found that bystander-initiated cardiac-only resuscitation and conventional CPR were similarly effective for most out-of-hospital cardiac arrests. Also, laypersons may be more willing to provide CPR if mouth-to-

mouth breathing is not required.^{19–26} Our series expands on these principles, suggesting clinical benefit with passive ventilation as the initial ventilation technique.

The clinical application of our findings presents potential challenges. Because we observed benefit for the witnessed ventricular fibrillation/ventricular tachycardia only, some EMS systems may choose to implement passive ventilation for ventricular fibrillation/ventricular tachycardia patients only. However, the clinical information initially available at an out-of-hospital cardiac arrest (including cardiac rhythm) is often not immediately available. The introduction of an additional interventional decision point may introduce complexity and potential confusion. Therefore, although our data suggest a passive ventilation benefit for witnessed ventricular fibrillation/ventricular tachycardia out-of-hospital cardiac arrest only, it may be operationally simpler to use initial passive ventilation on all out-of-hospital cardiac arrest. Further research is needed to identify the optimal method, rate, and amount of ventilation for nonshockable rhythm and unwitnessed

arrests. Our series evaluates initial ventilation strategy only. We do not know whether the nonshockable group would have appreciated benefit (or harm) if passive ventilation had been applied through the entire resuscitation.

Although survival in the unwitnessed and nonshockable cardiac arrest groups was higher for those receiving bag-valve-mask ventilation, this did not reach statistical significance. However, with a larger sample size, active ventilation may be the preferred airway management strategy for these subgroups of cardiac arrest. A larger series is needed to answer this question.

In Arizona, adult, witnessed ventricular fibrillation, out-of-hospital cardiac arrest victims who received minimally interrupted cardiac resuscitation with initial passive ventilation had higher adjusted neurologically intact survival rates than those treated with initial bag-valve-mask ventilation.

The authors thank Arizona's emergency medical providers for their participation in the SHARE program and their commitment to excellence in out-of-hospital care. The authors thank the following individuals from the Arizona Department of Health Services Bureau of Emergency Medical Services and Trauma System: Paula R. Brazil, MA, for her assistance in the preparation of this article; and Terry Mullins, MBA, and Joel Bunis, MBA, NREMT-P, for their key leadership in developing the Arizona EMS System.

Supervising editor: Henry E. Wang, MD, MS

Author contributions: BJB, GAE, LC, RAB, ABS, TFV, RWH, and KBK conceived the study. All authors designed the study. BJB, GAE, and LC supervised the conduct of the analysis. BJB and LC supervised the data collection. BJB and LC recruited the participating EMS agencies. LC and VC managed the data including quality control. VC provided statistical advice on study design and performed the final analysis of the data. BJB, GAE, RAB, ABS, and TFV drafted the article and all authors contributed substantially to its revision. BJB takes responsibility for the paper as a whole.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article that might create any potential conflict of interest. The authors have stated that no such relationships exist. See the Manuscript Submission Agreement in this issue for examples of specific conflicts covered by this statement.

Publication dates: Received for publication January 22, 2009. Revisions received March 27, 2009, and April 23, 2009. Accepted for publication June 15, 2009. Available online August 6, 2009.

Reprints not available from the authors.

Address for correspondence: Bentley J. Bobrow, MD, Department of Emergency Medicine, Maricopa Medical Center, 2601 E Roosevelt St, Phoenix, AZ 85008; 602-364-0580; E-mail bobrowb@azdhs.gov.

REFERENCES

1. Rosamond W, Flegal K, Furie K, et al. Heart disease and stroke statistics—2008 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation*. 2008;117:e25-146.
2. Rea TD, Pearce RM, Raghunathan TE, et al. Incidence of out-of-hospital cardiac arrest. *Am J Cardiol*. 2004;93:1455-1460.
3. Nichol G, Stiell IG, Laupacis A, et al. A cumulative meta-analysis of the effectiveness of defibrillator-capable emergency medical services for victims of out-of-hospital cardiac arrest. *Ann Emerg Med*. 1999;34(4 pt 1):517-525.
4. Bobrow BJ, Clark LL, Ewy GA, et al. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. *JAMA*. 2008;299:1158-1165.
5. Rea TD, Eisenberg MS, Sinibaldi G, et al. Incidence of EMS-treated out-of-hospital cardiac arrest in the United States. *Resuscitation*. 2004;63:17-24.
6. Kellum MJ, Kennedy KW, Barney R, et al. Cardiocerebral resuscitation improves neurologically intact adjusted neurologically intact survival of patients with out-of-hospital cardiac arrest. *Ann Emerg Med*. 2008;52:244-252.
7. Kellum MJ, Kennedy KW, Ewy GA. Cardiocerebral resuscitation improves adjusted neurologically intact survival of patients with out-of-hospital cardiac arrest. *Am J Med*. 2006;119:335-340.
8. Aufderheide TP, Lurie KG. Death by hyperventilation: a common and life-threatening problem during cardiopulmonary resuscitation. *Crit Care Med*. 2004;32(9 suppl):S345-351.
9. Aufderheide TP, Sigurdsson G, Pirrallo RG, et al. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. *Circulation*. 2004;109:1960-1965.
10. US Census Bureau. American fact finder, population fact finder. Available at: <http://quickfacts.census.gov/qfd/states/04000.html>. Accessed November 21, 2008.
11. Bobrow BJ, Vadeboncoeur TF, Clark L, et al. Establishing Arizona's statewide cardiac arrest reporting and educational network. *Prehosp Emerg Care*. 2008;12:381-387.
12. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation*. 2004;110:3385-3397.
13. Cummins RO, Chamberlain DA, Abramson NS, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. *Circulation*. 1991;84:960-975.
14. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 3: adult basic life support. *Circulation*. 2000;102(8 suppl):122-159.
15. Steen S, Liao Q, Pierre L, et al. Continuous intratracheal insufflation of oxygen improves the efficacy of mechanical chest compression-active decompression CPR. *Resuscitation*. 2004;62:219-227.
16. Hayes MM, Ewy GA, Anavy ND, et al. Continuous passive oxygen insufflation results in a similar outcome to positive pressure ventilation in a swine model of out-of-hospital ventricular fibrillation. *Resuscitation*. 2007;74:357-365.

17. Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): an observational study. *Lancet*. 2007;369:920-926.
18. Iwami T, Kawamura T, Hiraide A, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. *Circulation*. 2007;116:2900-2907.
19. Locke CJ, Berg RA, Sanders AB, et al. Bystander cardiopulmonary resuscitation. Concerns about mouth-to-mouth contact. *Arch Intern Med*. 1995;155:938-943.
20. Shibata K, Taniguchi T, Yoshida M, et al. Obstacles to bystander cardiopulmonary resuscitation in Japan. *Resuscitation*. 2000;44:187-193.
21. Jelinek GA, Gennat H, Celenza T, et al. Community attitudes towards performing cardiopulmonary resuscitation in Western Australia. *Resuscitation*. 2001;51:239-246.
22. Hubble MW, Bachman M, Price R, et al. Willingness of high school students to perform cardiopulmonary resuscitation and automated external defibrillation. *Prehosp Emerg Care*. 2003;7:219-224.
23. Johnston TC, Clark MJ, Dingle GA, et al. Factors influencing Queenslanders' willingness to perform bystander cardiopulmonary resuscitation. *Resuscitation*. 2003;56:67-75.
24. Donohoe RT, Haefeli K, Moore F. Public perceptions and experiences of myocardial infarction, cardiac arrest and CPR in London. *Resuscitation*. 2006;71:70-79.
25. Taniguchi T, Omi W, Inaba H. Attitudes toward the performance of bystander cardiopulmonary resuscitation in Japan. *Resuscitation*. 2007;75:82-87.
26. Hew P, Brenner B, Kaufman J. Reluctance of paramedics and emergency medical technicians to perform mouth-to-mouth resuscitation. *J Emerg Med*. 1997;15:279-284.

CORRECTION NOTICE

In the August 2009 issue, in the article by Ruygrok et al ("Validation of 3 Termination of Resuscitation Criteria for Good Neurologic Survival After Out-of-Hospital Cardiac Arrest,"; pages 239-247), the column headings in Table 4 were incorrect. They should have been "Yes," "No," and "Total." We apologize for the error.

Table E1. Generalized estimating equation predicting overall survival and survival among subgroups.

Predictors	ROSC (N=1,019)	Overall Survival (N=1,019)	Survival Among VF Witnessed (N=222)	Survival Among VF Not Witnessed (N=99)	Survival Among Patients With Nonshockable Rhythm (N=697)
			OR (95% CI)		
Ventilation method, PV (reference=BVM)	0.8 (0.7–1.0)	1.2 (0.8–1.9)	2.5 (1.3–4.6)	0.5 (0.2–1.6)	0.3 (0.1–1.0)
Bystander CPR, performed (reference, not performed)	1.0 (0.8–1.3)	1.1 (0.8–1.5)	1.4 (1.0–2.0)	0.9 (0.3–2.8)	0.6 (0.3–1.3)
Initial rhythm, nonshockable (reference, shockable)	0.4 (0.3–0.5)	0.1 (0.1–0.2)	NA	NA	NA
Sex, female (reference, male)	1.7 (1.4–2.0)	1.4 (0.9–2.0)	2.0 (1.2–3.3)	0.7 (0.2–3.0)	0.9 (0.3–2.3)
Witnessed (reference, not witnessed)	3.5 (2.6–4.8)	4.1 (2.9–5.9)	NA	NA	4.7 (2.2–10.2)
Age,	0.99 (0.98–1.01)	0.97 (0.96–0.98)	0.96 (0.95–0.97)	0.97 (0.94–0.99)	0.99 (0.97–1.02)
EMS dispatch to arrival time	0.9 (0.8–1.0)	0.9 (0.7–1.1)	0.9 (0.8–1.1)	0.7 (0.6–0.8)	0.9 (0.6–1.4)
Location, home (reference, medical facility/public place)	0.8 (0.7–1.1)	0.8 (0.5–1.4)	1.0 (0.6–1.6)	0.4 (0.1–1.0)	0.7 (0.2–2.5)